AES Review

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NLSI Mission

- Conduct collaborative research in all areas of lunar science, enable cross-disciplinary partnerships throughout the lunar science community
- Provide scientific and technical perspectives to NASA on its lunar research programs and missions
- Explore innovative ways of using information technology for scientific collaboration between geographically disparate teams
- Train the next generation of lunar scientists with research opportunities for undergraduate and graduate students
- Encourage Education and Public Outreach through formal education content development, informal student programs and participatory public events

NLSI at a Glance







NLSI has seven competitively selected domestic and seven international teams

Teams focus on collaborative, interdisciplinary lunar research designed to support NASA's scientific and exploration goals

NLSI is currently in the fourth year of operation; teams are supported through multiple year cooperative agreements with NASA ($13M per year for 7 Teams)

Lunar science at NLSI is broadly defined to include studies:

Of the Moon: Investigating the composition, structure and history of the Moon as each relates to the evolution of the Earth, Moon and Solar System

On the Moon: Investigating the effects of lunar material and the environment on terrestrial life and robotic equipment

From the Moon: Exploring science that is uniquely enabled by being on or near the Moon, including celestial and Earth observations

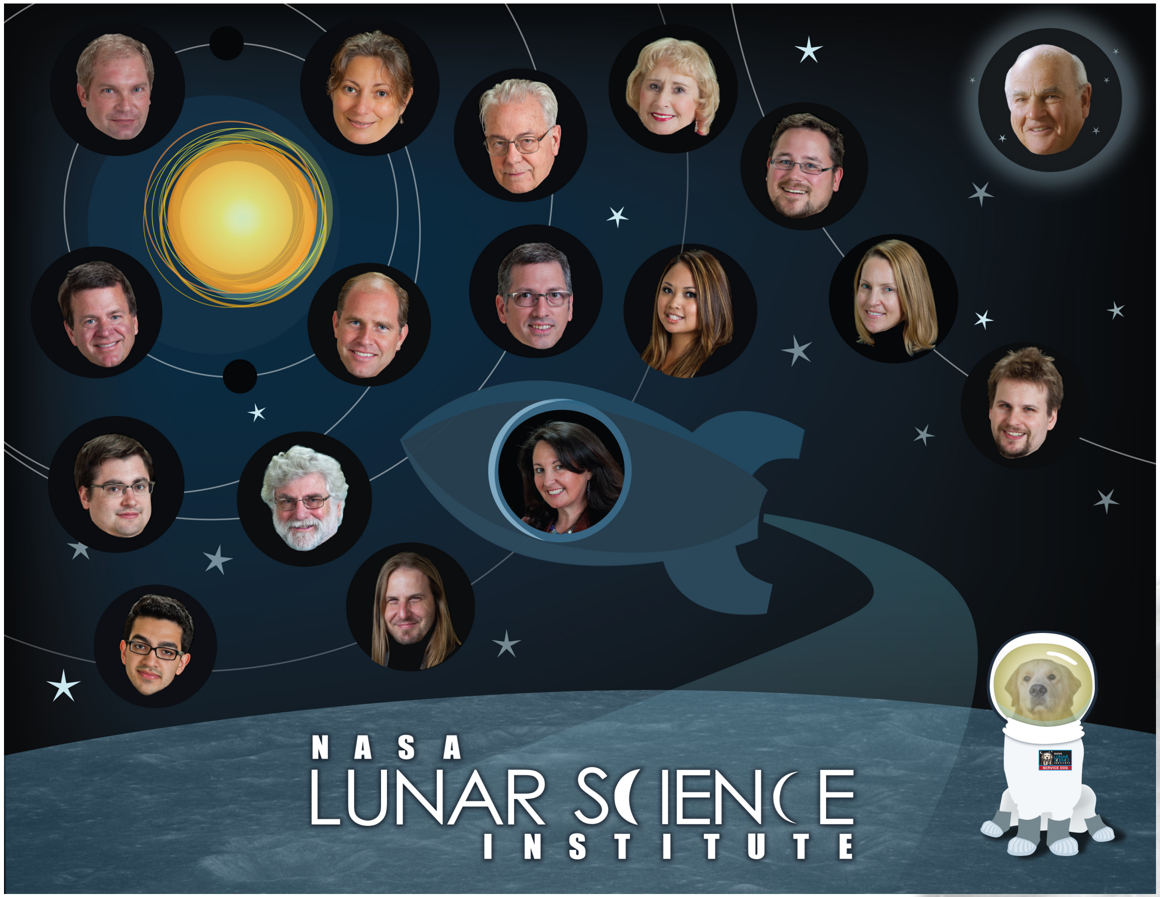






NLSI Central Office

NLSI's small central office at NASA Ames Research Center forms the organizational and collaborative hub for the domestic and international teams (>180 individuals)



Project Success Criteria Reflect AES Program Objectives

AES Objectives	Project Success Criteria
Rapid development and demonstration of prototype systems	NLSI Prototype systems developed by teams and open to entire lunar community: • U of Colo. Dust Accelerator, completed ahead of schedule (first 1.5 yrs) • U of Colo. Lunar Environment Simulator • Brown U. Spectroscopy Laboratory
Pioneer innovative approaches to improve affordability	• Virtual collaborative tools reduce travel cost associated with in-person meetings and workshops and reach a wider global audience
Create opportunities for the NASA workforce to gain hands-on experience and learn new skills	• Training NASA Civil Servants and contractors in the use of virtual collaborative tools • Creating a pipeline for the next generation into the NASA workforce
Multi-disciplinary, highly-collaborative project teams working across organizational lines	• The institute creates a bridge between SMD and HEOMD, uniting science and exploration • NLSI brings together multiple NASA centers: GSFC, MSFC, GRC, JPL, ARC, JSC– including international partners

Project Success Criteria Reflect AES Program Objectives

AES Objectives	Project Success Criteria
Infuse new technologies and capabilities into exploration missions	• New exploration technologies include: Kapton film deployment and testing, new wheel designs, camera/ mast height determination, surface deployment of small payloads from central lander, advanced retro-reflectors, regolith excavation
Leverage partnerships to amplify investments	• Institute leveraged partnerships and cost-sharing with several universities (e.g. across SMD divisions, DLR, and U of Colorado)
Outreach	• Citizen Science: MoonZoo, MoonMappers • Formal education: teacher workshops, K-14 STEM development, Journey through the Universe • Public events: eclipse observations, Int'l Observe the Moon Night, Int'l Year of Astronomy
Create and support lunar science and exploration community	• Lunar Science Forum • Focus Groups • NGLSE/LunarGradCon • Student Exchange Program • Lunar Intern Program @ LPI • NLSI Postdoctoral Fellow Program (NPP)

Financial Status

- The original CAN-1 teams are in their 4th year of operation and are scheduled to conclude their cooperative agreements in April, 2013
- $1.1M per year of HEOMD funds are sent to NLSI and are disbursed among all 7 teams
- In FY11, HEOMD sent an additional ~$2.3M to forward-fund NLSI teams
- HEOMD management has committed $4.3M per year for CAN-2 teams, which will be selected and funded by the end of FY13

HEOMD-Relevant Research

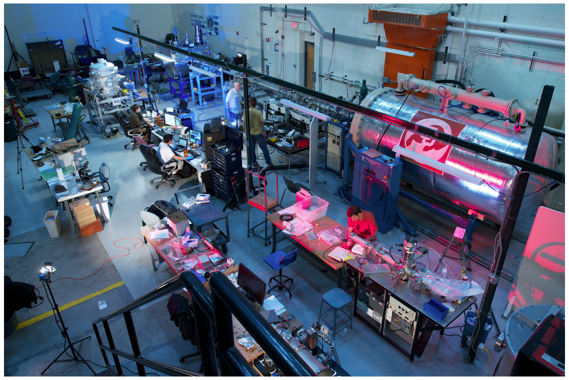
- Initial investment of $1.1M per year from ESMD/HEOMD beginning in 2009
  - The JHU/APL team, selected by ESMD as the "Exploration Team," focuses on civil engineering, volatile identification & ISRU in the lunar polar environment
- However, a significant portion of NLSI research is relevant to HEOMD, and has resulted in a large amount of exploration-related productivity in the first 3 years
- NLSI has strong international partnerships with member nations of the International Space Exploration Coordination Group (ISECG) that could be leveraged for new exploration-centered collaborations

HEOMD Relevant Accomplishments: Operations

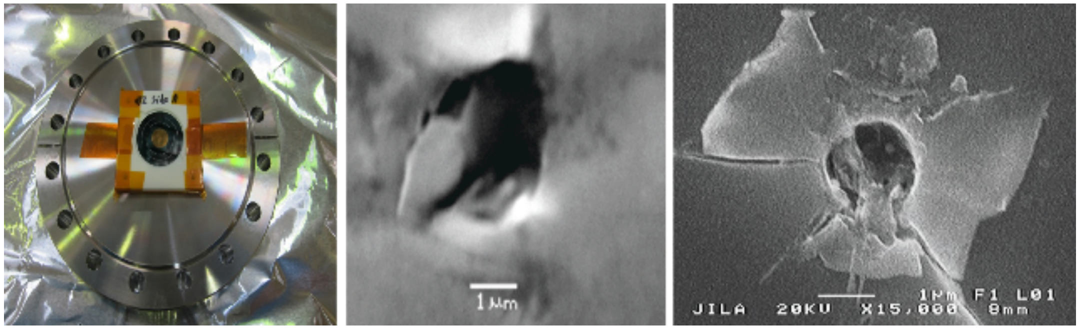
- Correlated lighting conditions and Earth-viewing positions near lunar poles which would be sufficient for future robotic operations and human lunar bases (Bussey)
- Determined grounding potential for robots and astronauts (Farrell)
- Developed world's fastest dust accelerator for impact studies (Horanyi)
- Studied impacts created by propulsion-induced ejecta (Horanyi)

The CCLDAS dust facility is a user facility open to the scientific community to assist with instrument calibrations and experiments.

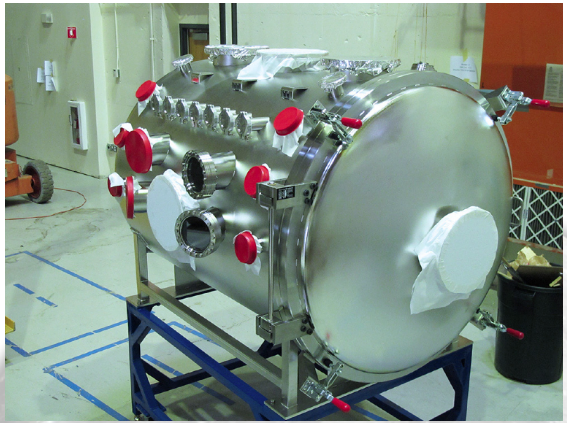
Quick Accelerator Facts:
* Energies up to 3 MV
* Particle sizes: 0.2 – 2.5 microns
* Particle velocities: 1 – 100 km/s



The 3 MV dust accelerator installed at the CCLDAS Lunar Environment and Impact Laboratory. The facility is now operational and available for the lunar community for impact studies.



[Left] Foil sample as used on Solar Probe Plus. [Center] Photograph shows penetration damage at high magnification. [Right] Micrometeoroid damage to a fused quartz retroreflector sample.



The Lunar Environment and Impact Laboratory simulates the variable plasma conditions on the lunar surface.

HEOMD Relevant Accomplishments: Operations Cont.

- Developed new wheel designs and regolith excavation methods (Bussey)
- Tested materials for long duration space exposure (Burns)
- Studied new drilling methods for instrumentation implantation (Burns)
- Studied superconducting bearings for pointing or orientation control (Burns)
- Developed methods for robotic deployment of sensors and lunar farside radio arrays (Burns)

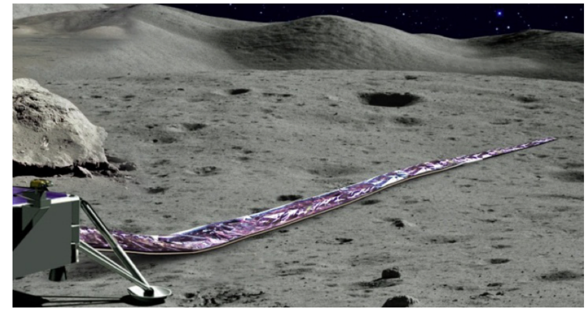
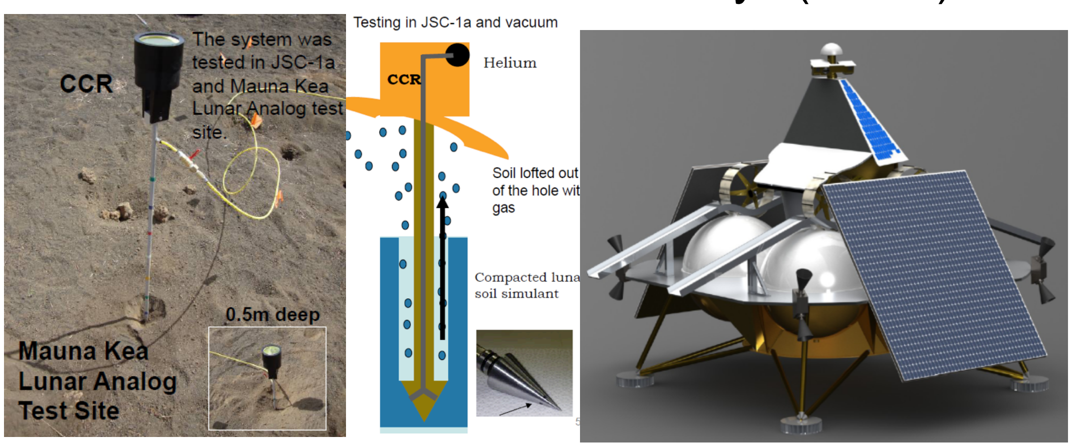
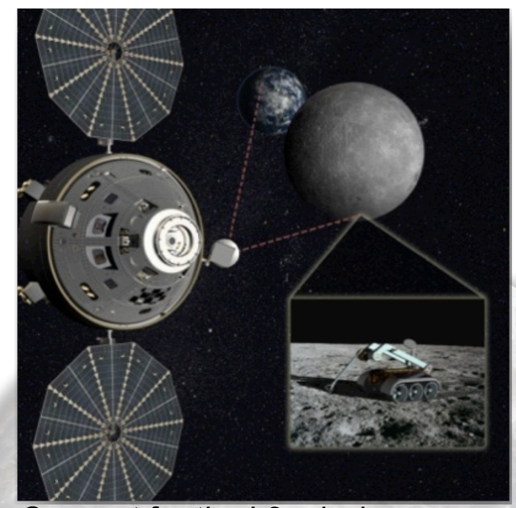


Figure 2. Artist's concept of a lander with a short length of polyimide film including two deposited dipole antennas (ROLSS prototype).



[Left & Center] Gas assisted drilling tool developed by Honeybee Robotics with support from LUNAR. [Right] Astrobotics lander, including the Honeybee drill, is being proposed to deploy a next generation lunar laser retroreflector as part of the Google Lunar X-Prize competition.



Concept for the L2 mission teleoperating a rover on the farside of the Moon via the Orion Crew Module.

HEOMD Relevant Accomplishments: Volatiles / ISRU

- Permanently shadowed regions have been found down to 58 degrees latitude with potential for water/ ice availability (Bussey)
- Investigations found volatile (OH/H2O) implantation within the regolith through solar wind interactions with airless bodies (Farrell)
- OH identification across the entire lunar surface indicates ISRU potential (Pieters)
- Geochemical characterization of lunar materials found to be relevant to ISRU engineering purposes (Bussey, Burns, Kring/Bottke)

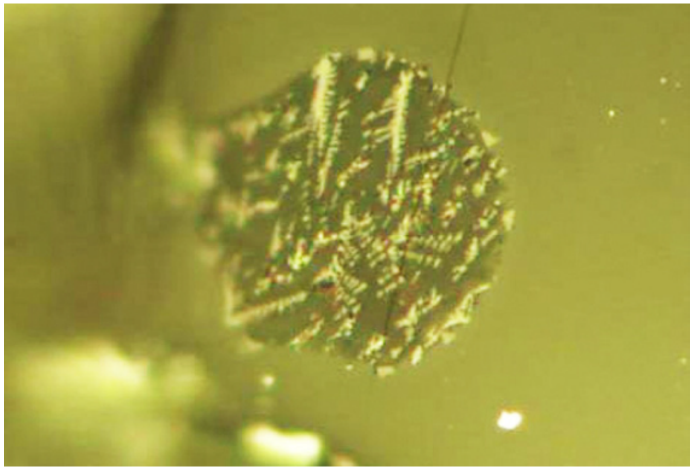
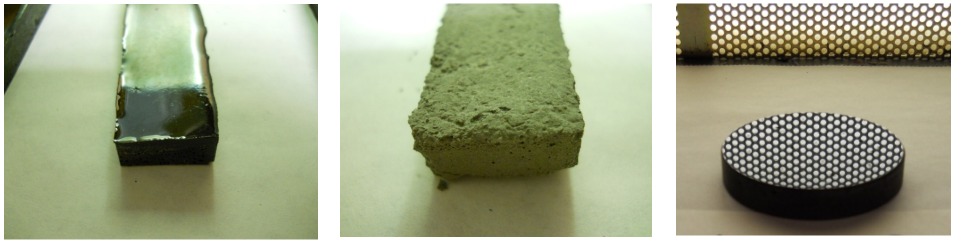
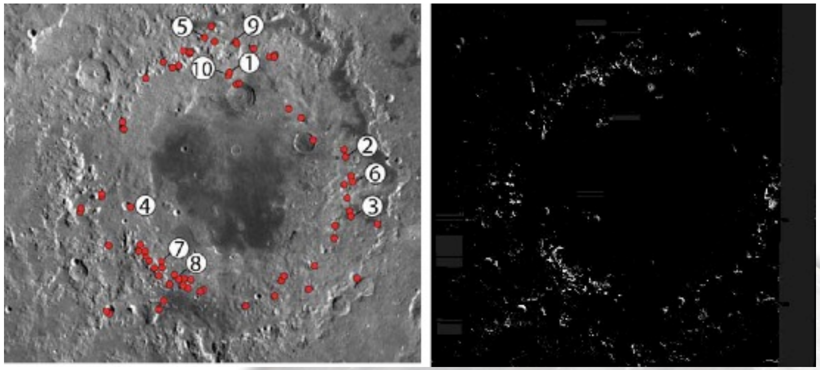


Figure 3. Volatile content of melt inclusions [Hauri et al., 2011].



Left & Center: Samples of 'lunar cement' made with lunar regolith simulant and epoxy at different proportions. On the left is a 3:1 sample. At 5:1 (center), the material was crumbly and had very low structural strength. Right: A 5 cm diameter lunar cement disk was polished into an optical flat. The experiment suggests that future telescopes on the Moon can be made in-situ using lunar dust.



[Left] Outcrops of crystalline anorthosite identified in the Orientale region with Chandrayaan/Moon Mineralogy Mapper (M3) data. [Right] Band depth for OH feature at 2.8μm across the Orientale region derived from M3 data.

HEOMD Relevant Accomplishments: Environment

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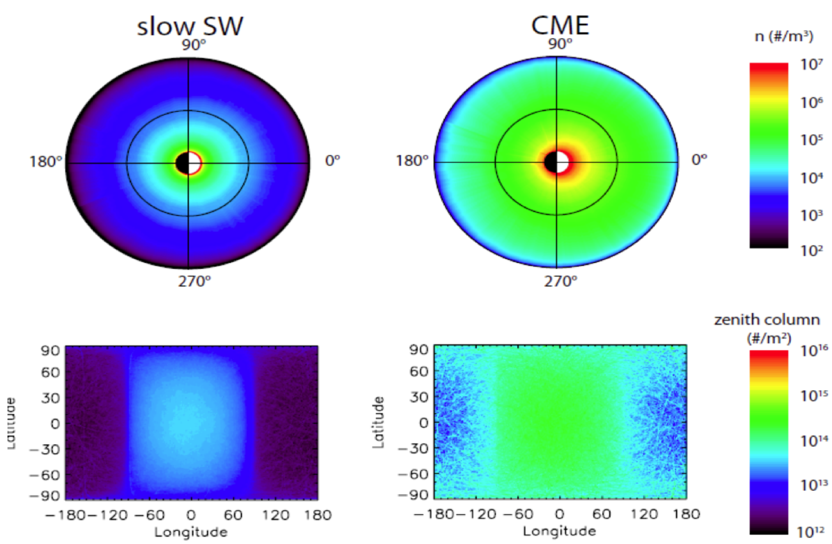
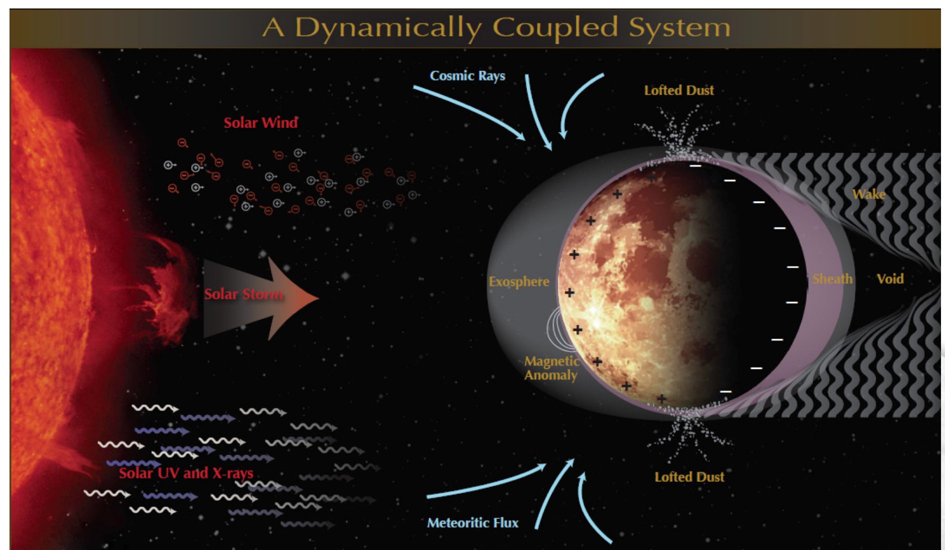
- Characterized the space plasma environment interaction with lunar surface (Farrell, Bussey)
- Modeled solar energetic particle radiation during CMEs (Farrell)
- Researched degradation of array materials over time as affected by space plasma and dust transport mechanics (Farrell, Horanyi & Burns)



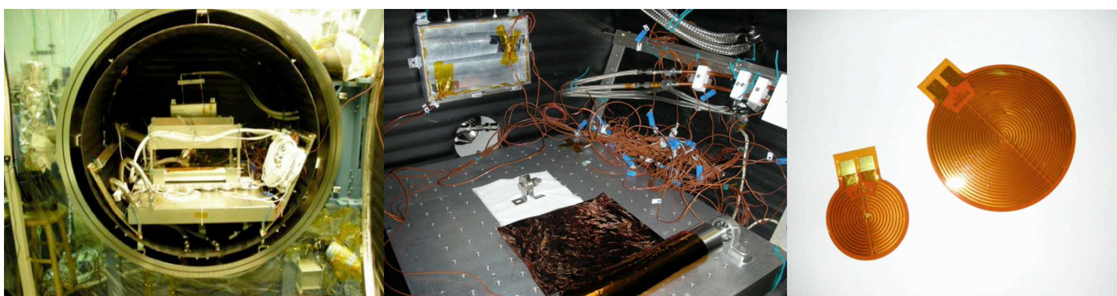
The enhancement in the sodium exosphere from CME sputtering (from Killen et al. 2012)



The solar-lunar connection studied by the DREAM lunar environment center.

HEOMD Relevant Accomplishments: Environment Cont.

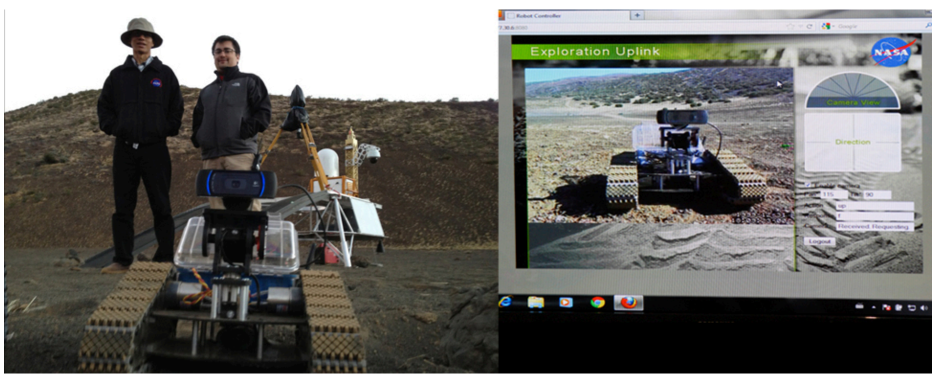
- Characterized interaction between lunar exosphere and surface release of molecules (Farrell)
- Detailed study of micro-meteorite impacts (Horanyi)
- Studied surface charging in and around craters, the terminator and shadows of spacecraft (Horanyi)
- Developed a Lunar Simulation Laboratory to mimic unique conditions on the Lunar surface (Burns)
- Characterization and effects of lunar dust transport (Horanyi)



[Left] The Lunar Simulation Laboratory vacuum chamber. [Center] a roll of copper-coated Kapton film has been mechanically unrolled, exposed to repeated thermal cycling from -150 C to 100 C, and exposed to hard ultraviolet radiation during the "day" cycle. [Right] Kapton films with embedded electrical circuits are shown which mimic the simplest components of a radio telescope array.

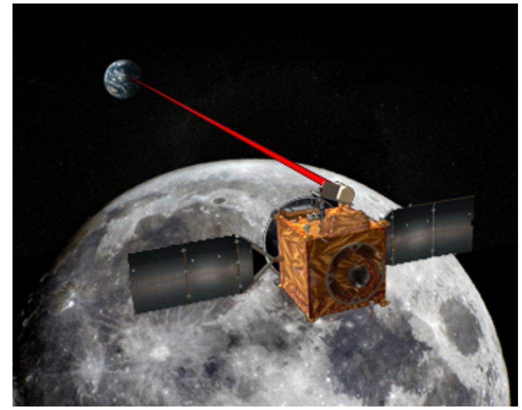
HEOMD Relevant Accomplishments: Field Training

- Cratering mechanics and geologic field training
    - Meteor Crater (Kring)
    - Sudbury Crater (Osinski, NLSI-Canadian partner)
    - Desert Rats (DRATS) in AZ (Kring)
- K10 Rover array deployment (Burns)
- Lunar Exploration Rover (LER) field testing and operations at Black Point, AZ (Kring)
- Exploration Uplink, remote operations (NLSI)
- RESOLVE field testing in Hawaii (NLSI)



Mission simulation at the Black Point Lava Flow planetary analogue site.

NLSI Collaborations



- Important International collaborations:
  - Bussey and British collaborators working on thermal modeling and analog samples
  - Pan-European lunar science consortium created in 2010 by NLSI
  - UK leading European lunar volatiles community
  - Kring and Canada developing “field school” relevant to ground truth for remote sensing and astronaut training

Plans for FY13

- Expansion of the Institute to include NEAs, and Phobos/Deimos
  - CAN to be issued late 2012
  - Selection and funding of new teams in mid-2013
    - $13M/yr ($4.3M from HEOMD)
- Address key HEOMD strategic goals
  - CAN will address HEOMD Strategic Knowledge Gaps
  - Expand upon L2/Farside science and telerobotic operations concept developed by multiple NLSI teams
  - Continue development of international partnerships to focus on strategic HEOMD goals

Lessons Learned

Longer periods of performance and higher funding levels resulted in:

- Unexpected benefits (relevant to HEOMD) from multiple teams
- Rapid response to changing research environments
- creating inter-team and interdisciplinary collaborations
- and long term stability for student and future workforce development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